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EIC Detector R&D Progress Report

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Project Name : R&D for a Compton Electron Detector
Period Reported: from 07/22/2017 to 12/29/2017
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Abstract

Precision polarimetry is an important component for the EIC. It aims at reaching 1% level precision. Compton Polarimetry is commonly use for electron polarimetry. It allows a non invasive measurement of the electron polarization. Accuracies up to 0.52% were achieved using the Compton Electron detection. Sub-percent precision is foreseeable for EIC though the significantly higher current and space constraints require an extensive study. This proposal is looking at the option of a semi-conductor detector in a Roman Pot chamber to detect the Compton electrons.

EIC Detector R&D Progress Report

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1 Progress Report Section

1.1 Past

1.1.1 What was planned for this period?

Here is the list of task that were approved by the committee for fiscal year 2017.

- more realistic design of Roman Pot geometry in simulation (was simply a plate for now)
- optimize number of strips and strip size for best systematics with as few channels as possible
- optimization of thin window for improved systematics
- determination of expected accuracy of the measurement
- determine the contribution of beam induced background using molflow and synrad package

1.1.2 What was achieved ?

Strip size of the detector study was completed.

Rest of the studies is ongoing for the different energies.

2 Report

2.1 Compton Simulation (work by Joshua Hoskins postdoc at University of Manitoba supervised by David Gaskell and Alexandre Camsonne)

Building on the simulations thus far we have worked to expand our focus to new energies as well as adding systematic studies of the detector response. Thus far we have worked on determination of signal-to-noise and background contributions due to halo via simulation. This work required construction of beamline and detector models in GEANT4 as well as development of Compton electron generator and halo generator. Results from the our model are cross-checked with our GEANT3 model when appropriate. We present here a an overview of the software development and initial results of background and systematics results we have achieved thus far for both 3 GeV and 5 GeV. We expect to add 11 GeV, as well improving and expanding our results, in our final report.

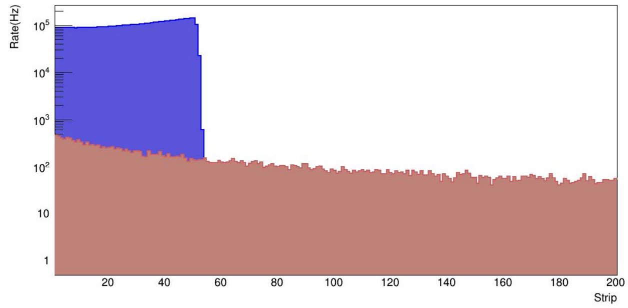

Figure 1: Rate as seen in electron detector at 3 GeV. The Compton scattering rate is shown in blue and the background rate is show in salmon. The background rate does not include halo or upstream events.

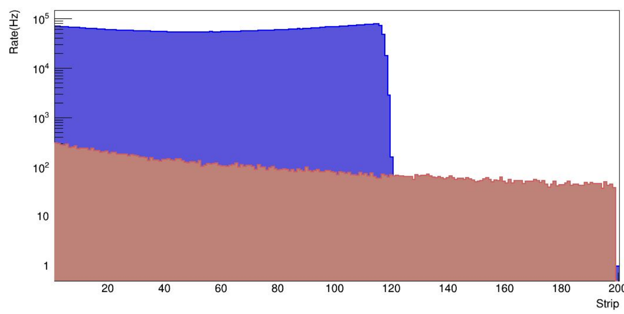

Figure 2: Rate as seen in electron detector at 5 GeV. The Compton scattering rate is shown in blue and the background rate is show in salmon. The background rate does not include halo or upstream events.

2.2 Software Development

For the purposes of the Compton simulations, a full software suite has been developed. For our last report we developed generators that provided both Compton events and an estimate of the halo. With our focus shifting to a wider range of energies and new ambitions of looking at systematics in the electron detector, a more integrated functional package was needed to avoid constantly reediting ROOT macros. Equally important was the fact that all the software needed to connect seamlessly to the batch farm at Jefferson Lab. With this in-mind, a fully integrated analysis suite that allowed for easy access scientific computing, fully customizable detector and beam energy parameters, all available to the working group via github, was developed. In addition, the Compton fitting was changed to work with all beam energy settings and allow the detector properties to be changes as need; this is especially important for the detector systematics work.

2.3 Compton Analysis

2.3.1 Detector Rate

We have preformed GEANT4 simulations to characterize the electron detector rate and signal-to-noise ratio. Simulations were done for a single pass, CW laser with 10 W of power. The beam energies used were 3 GeV and 5 GeV at 1A current and the beamline vacuum was set to be 10^{-9}. Signal-to-noise results for both the energies are shown in Figure 1 and 2 respectively.

In both cases the signal is $\mathcal{O}(100)$ above the background. Contributions from the upstream IP are not included as they were found to be sub-hertz level. Backgrounds due to halo effects are discussed in more detail in Sec. 2.3.2. Additionally, the Compton asymmetry in the electron detector, for both energies, was simulated and can be seen in Figures 4 and 5. For comparison the expected theoretical asymmetry for all three energies of interest are shown in Fig. 3. Both simulated asymmetries match the theoretical expectations.

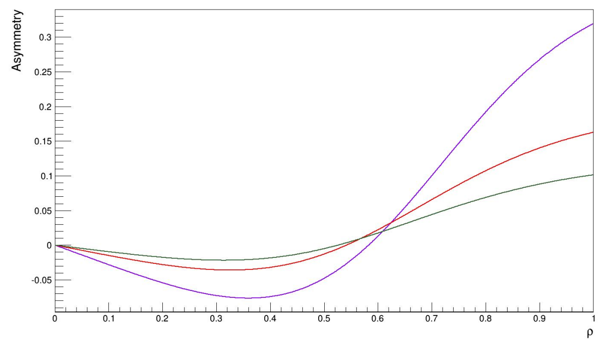

Figure 3: Theoretical asymmetries for each energy level produced by the Compton generator. The asymmetries are 3 GeV (green), 5 GeV (red), 11 GeV (purple) respectively.

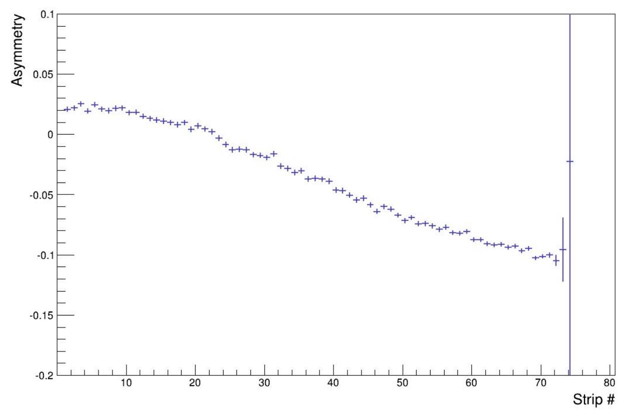

Figure 4: The simulated Compton scattering asymmetry as seen in electron detector at 3 GeV.

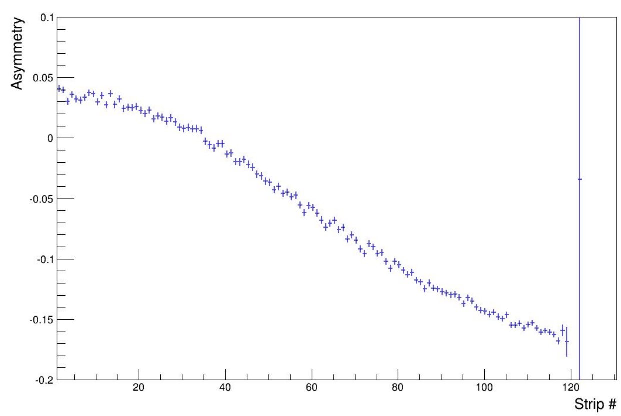

Figure 5: The simulated Compton scattering asymmetry as seen in electron detector at 5 GeV.

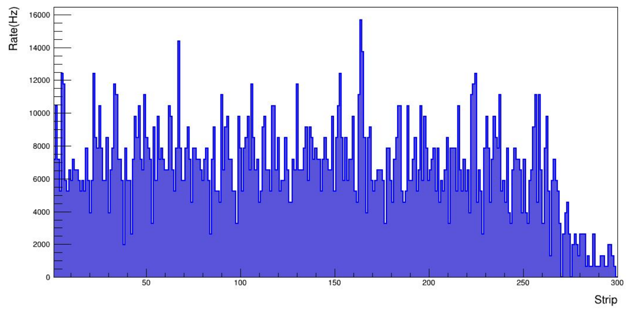

Figure 6: Background due to the halo interacting with the apertures at 3 GeV. This rate can be lowered further by making the aperture slots slightly bigger.

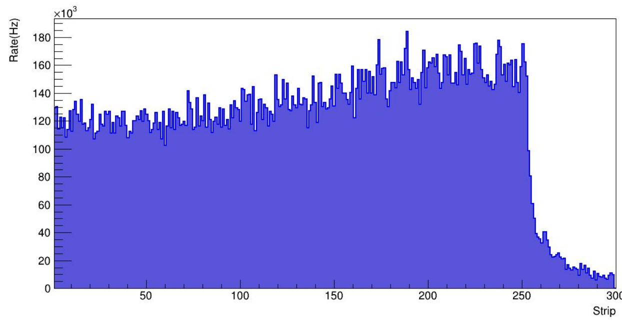

Figure 7: Background due to the halo interacting with the apertures at 5 GeV. This rate can be lowered further by making the aperture slots slightly bigger.

2.3.2 Halo Study

Backgrounds due to halo are generated primarily from two sources, halo interaction with mirror apertures associated with a Fabry-Perot cavity in the Compton chicane and direct interaction of the halo at the electron detector. For this report results for 3 GeV and 5 GeV interactions with the apertures is discussed. Direct interactions with the detector will be discussed in the final report.

The halo was modeled using a double Gaussian distribution as described in the PEPII report and is given by,

$$\frac{dN}{dxdy} = e^{-\frac{x^2}{2\sigma_x^2} - \frac{y^2}{2\sigma_y^2}} + Ae^{-\frac{x^2}{2(S_x\sigma_x)^2} - \frac{y^2}{2(S_y\sigma_y)^2}}.' \tag{1}$$

Results for both energies are shown in Figures 6 and 7. Both background are small with respect to the Compton signal. One key point that must be mentioned is the fact that no good estimate of the halo amplitude, given in Eq. 1 as A, exists at the moment. While the rate due to interaction with the apertures is relatively small, the rate due to direct interaction with the detector, as seen from the studies in the previous report, is extremely large depending on the choice amplitude.

2.3.3 Detector Systematics

The main goal of the detector systematics study was to determine how the detector strip width affects the measured polarization and what the minimum number of strips (maximum strip width) is. The study was carried out by simulating the asymmetry in the electron detector and then using the fitting software to calculated the measured polarization. A feature was added to the fitting software to allow the size of each strip to be varied while keeping the total detector size fixed. Using this we were able to use increasingly fewer strips and look at how the measured asymmetry changed. This gives us the effective minimum resolution of the detector. The results from the study for both energies can be seen in Table 1.

Plotting the fitted asymmetry versus the effective number of strips it can be seen that the ability of the fitting algorithm to correctly determine the polarization breaks down once the number of strips is

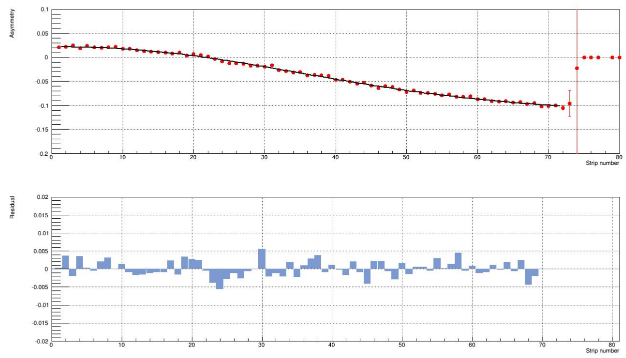

Figure 8: Fit of the Compton asymmetry at 3 GeV. The fit residuals are shown below the fit.

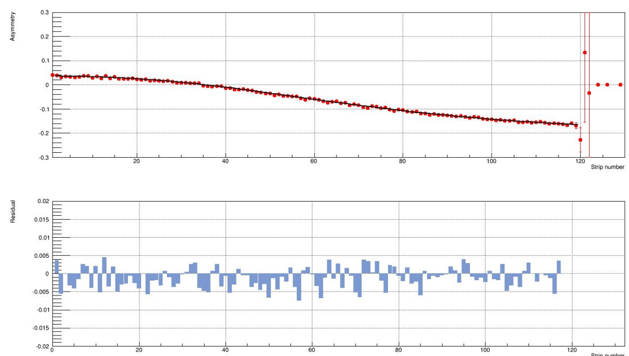

Figure 9: Fit of the Compton asymmetry at 5 GeV. The fit residuals are shown below the fit.

Multiplier	Energy (GeV)	Polarization	χ^2/NDF
1	5	-100.00 $\pm$ 0.06	1.17
2	5	-100.00 $\pm$ 0.08	1.12
5	5	-100.00 $\pm$ 0.04	1.23
10	5	-100.00 $\pm$ 0.05	2.12
12	5	-100.00 $\pm$ 0.05	2.62
20	5	-98.00 $\pm$ 0.36	24.75
1	3	-100.00 $\pm$ 0.40	0.87
2	3	-100.00 $\pm$ 0.13	1.09
5	3	-100.00 $\pm$ 0.10	1.87
10	3	-100.00 $\pm$ 0.11	2.98
12	3	-100.00 $\pm$ 0.26	2.74
20	3	-97.20 $\pm$ 0.62	17.16

Table 1: Compton fit results.

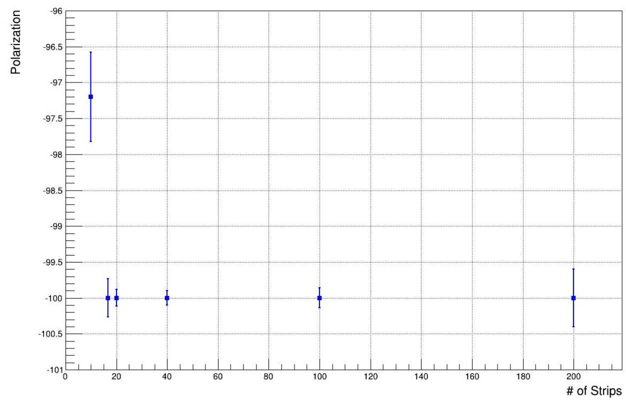

Figure 10: Fit calculated polarization results for different detector resolutions at 3 GeV.

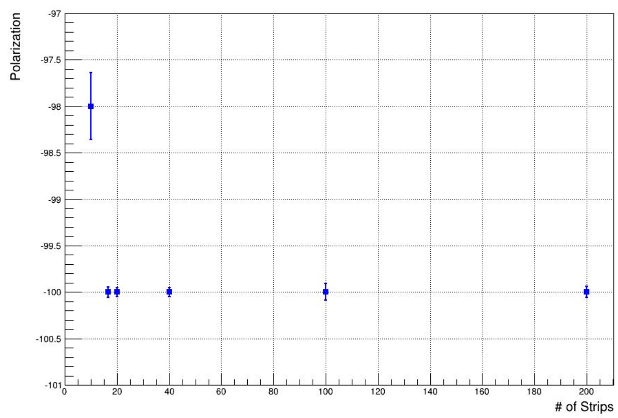

Figure 11: Fit calculated polarization results for different detector resolutions at 5 GeV.

reduced by a factor of 20. Figures 11 and 9 show results for both energies.

3 Future Plans

There is much that we would still like to accomplish in the second half of the study. In the last 6 months there has far more software work than was originally anticipated but now we have a versatile set of software packages that will allow us work more efficiently and faster. One of the main focuses will be to add in 11 GeV beam in to all of the above studies and take another look at the halo contribution at the electron detector. We would like to work with the accelerator group to get a better estimate of what the size of the halo amplitude will be so that we can get a more realistic result. We would also like to take a look at effects from synchrotron radiation. To date this has not been possible with GEMC because it was not added into the process ID in the software making it impossible to access sychrotron events. This has been worked on recently however and we should be able access the events now. Some work will need to be done to determine how well GEANT4 estimates synchrotron radiation as well.